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PHOTOACTIVATED SWITCHES AND APPLICATIONS

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Photoactivated or optoelectronic switches whose resistance is controlled by light are being developed by DARPA at NOSC for sampling and control of electrical signals. The benefits offered include high speed, signal-control isolation, and compatibility with RF/microwave transmission lines. Furthermore the use of optical fibers to transmit light to the switches, yields complete switch isolation, absence of pickup, excellent timing control, and low jitter. Several application areas are being studied and developed including ultra high speed (50 ps) sampling of digital signals for time division multiplexing [1], sampling of a microwave signal for coherent radar, and reconfiguring of RF/microwave antenna elements. We review the simple model of photoconductor design, including trade-offs between switch resistance and capacitance for radar and antenna applications and present some preliminary experimental data on silicon switches.

For simplicity, consider a photoconductor slab of length L , with ohmic contacts to two metal plates of area A . In terms of photoconductivity σ , and dielectric constant ϵ , the switch resistance R , and capacitance C , can be estimated as:

$$R = \frac{L}{\sigma A} \quad 1)$$

$$C = \frac{\epsilon A}{L} \quad 2)$$

Under no optical excitation $\sigma_{\text{off}} = n_i e \mu$, with n_i the initial carrier concentration, and μ the sum of the electron and hole mobilities. Under excitation of optical power P , with photon energy $h\nu$, the photoconductivity becomes:

$$\sigma_{\text{on}} = \frac{P \tau}{h \nu L A} e \mu \quad 3)$$

Combination of equations (1) and (2) gives $RC = \epsilon / \sigma$, a more general expression, independent of switch geometries. This implies that it is difficult to achieve low R_{on} and low C simultaneously. For example, low capacitance improves isolation when microwaves are to be switched. However, the price to be paid is high R_{on} , which reduces the microwave switching efficiency. We consider use of only diode lasers, for practicality. To achieve $R_{\text{on}} \approx 1 \Omega$ and $C \approx 10 \text{ fF}$ for radar and antenna applications such as reconfigurable antennas, silicon is chosen because of its high photoconductivity associated with long (microseconds to milliseconds) carrier lifetime (τ), as compared to nanosecond lifetimes for III-IV semiconductors.

With silicon switches optimized for high speed sampling, we obtained $R_{\text{on}} = 38 \Omega$ under 15 mW CW excitation from a 670 nm laser diode. This $2 \mu\text{m}$ finger and $2 \mu\text{m}$ gap interdigitated switch has a capacitance of 60 fF. We project that a silicon switch designed specifically for antenna applications will yield $R_{\text{on}} \approx 1 \Omega$ under 20 mW optical excitation, $R_{\text{off}} \geq 1 \text{ k}\Omega$, $C \approx 10 \text{ fF}$, and microwave power $\geq 2 \text{ W}$.

1. C.T. Chang, et al, "Optoelectronic Switches and Multigigabit 8:1 Time Multiplexer," IEEE Transactions on Electron Devices, Vol. 37, No. 9, September 1990, pp. 1969-.

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